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Sprinkler Irrigation: A Volatile Organic Compound Remediation Alternative

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A Volatile Organic Compound Remediation Alternative

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Purpose
Sprinkler irrigation has the potential not only to cheaply and effectively remove volatile organic compounds (VOCs) from contaminated ground water but also use the water beneficially and eliminate the costly disposal of both the remediated water and the contaminants. Removal of VOCs from water involves volatilization, which releases the VOCs from the liquid phase to the gaseous phase.

A conventionally designed sprinkler irrigation system was tested near Hastings, Nebraska, to assess its efficacy for removing VOCs in pumped ground water. VOCs in the ground water include 1,1,2-trichloroethylene (TCE), ethylene dibromide (EDB), 1,1,1-trichloroethane (TCA), and carbon tetrachloride (CT). Factors possibly influencing volatilization include nozzle size, system pressure, impact pad design, flow rate, and temperature.

Methods
A total of 340 equally spaced screw-in nozzles were mounted on a 858-ft center-pivot sprinkler irrigation system. The nozzles had interchangeable impact pads, and the diameter of the nozzle openings ranged from 5/64 in at the pivot head to 20/64 in at the end of the pivot arm. Impact pads evaluated were a grooved convex pad, a convex smooth pad, and a pad support only (without pad). The irrigation system remained stationary in a grassed area at the end of the field. Twelve stratified water droplet collectors, which could simultaneously collect spray at four fall heights (10.5 ft, 7.5 ft, 4.5 ft, and 1.5 ft) between the pivot arm and the ground, were evenly spaced along the pivot arm. Initial VOC concentrations were determined from samples collected at a hydrant at the pivot pad.

In summer 1994, researchers conducted two experiments with the convex smooth pad and with the pad support only (without pad) at inlet pressures of 30 psi and 45 psi. A third experiment with a grooved pad was conducted at 30 psi. Temperatures at the time of the experiments ranged from 74˚F to 94˚F. Winds speeds ranged from 5 mph to 14 mph. Water samples were immediately chilled and transported to a local laboratory.

Results and Discussion
Volatilization is strongly dependent upon the vapor pressure and the solubility of the chemical although factors such as turbulence and molecular diffusion also can influence volatilization. The order of volatility of the four analytes is CT>TCA>TCE>EDB. Other factors that potentially can effect the water to air transfer are the large changes in both temperature and pressure which occur as the ground water is pumped to the surface and released through the sprinkler irrigation system. Initially the temperature of the irrigation water is ≈50˚F and the pressure of the dissolved gases at a depth more than 65 ft beneath the water table is above 28 psi. During sprinkler irrigation the dissolved gases rapidly exsolve from a thin film formed at the impact pad and from the small droplets formed at the film's edge. Preliminary measurements indicate a 50% reduction in concentration within 1 ft of the nozzle. During its trajectory the water warms very quickly to a temperature of up to 68˚F. Results from the stratified water droplet collectors reveal a generalized pattern of low residual VOC concentrations in the

highest sampler and progressively lower concentrations as the height of the sampler above the ground surface decreases. The data from all the samplers 1.5 ft above the ground (Table 1) indicate that in the five pilot tests the efficacy of TCE remediation was very good regardless of the pad design, weather conditions, or flow rate. Removal efficiencies for TCE exceeded 98% for all five tests. Removal efficiencies for CT, TCA, and EDB were better than 95.5% for all five tests. VOC concentrations in samplers 1.5 ft above the ground were consistantly close to or below the maximum contaminat level for all four compounds. There was an obvious increase in efficacy of TCE at the higher pressure (Table 1). The increased flow rate that accompanies the increased pressure also increases mass removal of the contaminant. Efficacy also increased with a decrease in nozzle size.

The data indicate that most of the volatilization occurs in the space between the nozzle and the highest sampler. Subsequent remediation as the droplets fall between the 10.5-ft and 1.5-ft samplers is small and amounts to <5% of the total loss. Thus the evaluation of nozzle size and impact pad design on volatilization efficiency is an exercise to fine-tune an already very efficient volatilization methodology. Predicted atmospheric concentrations of the VOCs were well below levels requiring permits by the Nebraska Department of Environmental Quality.

Conclusions

High capacity wells and sprinkler irrigation systems can efficiently remediate VOC-contaminated groundwater and comply with the criteria necessary for containment and mass removal of the contaminants. The sprinkler irrigation treatment alternative provides a beneficial use for the treated water and eliminates the costly disposal of both the remediated water and the contaminants. Embracing the sprinkler irrigation alternative would save the taxpayer and those responsible for the cleanup millions of dollars in remediation costs. Inherent in the alternative treatment is irrigation, a farming practice vital to the successful production of small grains, fruits and vegetables in much of the high plains and western states.

Implications for Further Study

Additional research will be conducted to better determine optimal nozzle size and impact pad design.

Publications

Spalding, R.F, M.E. Burbach, M.E. Exner, L. Parra-Vicary, and D.R. Alexander. 1994. Sprinkler Irrigation: A VOC Remediation Alternative. Technology: Journal of The Franklin Institute, 331A:231-241.

Table 1. Field conditions and experimental results for TCE.

	July 6	July 28		August 12	
Sprinkler Pad	grooved convex	pad support without pad		convex	
Temp. (°F)	88	74		94	
Wind Speed (mph)	14	5		9	
Inlet Pressure (psi)	30	30	45	30	45
Flow (gpm)	1100	1100	1350	1100	1350
Ave. Input Conc. (µg/L)	445	608	650	452	435
Ave. Conc. (µg/L) (at 1.5 ft sampler)	8.2	9.0	8.2	5.5	1.9
Removed (%)	**98.2**	**98.5**	**98.8**	**98.8**	**99.6**

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